CLIMATE CHANGE ADAPTATION STRATEGIES: WATER RESOURCES MANAGEMENT IN SENEGAL AND SIERRA LEONE

by
Tanobla Aurelie Konin

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ABSTRACT

We may not have realized it yet, but climate change impacts are becoming much more significant. Communities and countries around the world are aware of the effects of climate change with the increasing number of hurricanes, tornadoes, floods and droughts events. Climate change is known to be a widespread phenomenon that is connected to how much greenhouse gases are emitted into the atmosphere, which in turn is associated with the rapid increase in the global temperature. The increase of these emissions is caused mainly by human activities such as the burning of fossil fuels, causing the massive emission of carbon dioxide and the loss of carbon storage in forests and other natural lands. The intensity of the emissions is determined by the level of industrialization and the level of technology of a community.

Many questions are being raised in relation to the causes, risks, vulnerabilities and impacts of climate change. As an Energy Policy and Climate graduate student at Johns Hopkins University, I have focused my coursework on Climate and Adaptation subjects such as Cities and Climate Change, Adaptation to Climate Change, Climate Change Policy Analysis among others. As a result, I became very interested in the many different adaptive measures that countries often use in order to limit the risks and vulnerabilities of the communities living in low resilience areas.

- Pollution of water resources is another problem that is rapidly graduating and worsens with economic development, population growth, and diversity of living standards and human activities. In many areas all over the continent, rainfall amounts over the years have reduced due to longer dry seasons,

leading to less surface and ground waters that could be useful for the population.

- The main purpose of this Capstone Project is to extend my knowledge and experience attained through coursework and work environment by studying least developed countries that do not have access to technology resources in order to achieve a certain level of climate change adaptation that could put West African Countries on the right path of sustainability development.
- Africa is a continent rich in natural resources. Many sectors in West Africa are impacted by climate change including water resources, coastal zone resources, agriculture, human health, energy, industry, forestry, fisheries and wildlife. Nevertheless, there are not many technological resources available to identify, and control the effect of climate change. In fact, in areas such as Sierra Leone and Senegal, communities are not aware of the causes and effects of climate change.
- The outcome expected in the end is first to identify the problem that has not been addressed by the local authorities, and then provide a framework of set of adaptive measures that could be implemented and could make a difference despite all the obstacles the communities of Sierra Leone and Senegal are facing.
- Skills and knowledge for this project were acquired from various relevant coursework and through an Internship at Environment America as a Clean Water Intern. Statistical data based on scientific research will be selected by

examining baseline risks and vulnerabilities as they affect water, and then response options in the water sector.

- Finding the best available data will help me use it to understand baselines and response options. In fact, as an example, in order to move forward with the project, an evaluation of the Business As Usual (BAU) activities will be a great start.
- A great addition to this project is the mentorship of Mr. Peterson, Founder, CEO and President of the Center for Climate Strategies. Then research and project documents will be evaluated to give a framework to address the problem.

Being a foreigner born and raised in the Ivory Coast, or Côte D'Ivoire, an emerging West African country, climate change is an occurrence that is being undervalued, and people are still suffering from the impacts of this phenomenon. Consequently, I decided to focus on the changes created by climate change and evaluate the consequent adaptation strategies put in place in specific region in Africa on the west coast basin of Africa, mainly countries like Senegal and Sierra Leone. Another purpose of this Project is to provide and describe a set of metrics that could be implemented towards the issues of water resources, the impacts of food activities, human health and industries, including food and energy adaptation strategies.

This project is referencing many data found through extensive research as well as unavailable information. In fact, as stated earlier, the project will be based on least developed countries in West Africa. This intends that many necessary data and helpful information will not be available. Climate change can have very serious negative effects

on the socio-economic development of a community, if the possible impacts and effects are not identified in order for the appropriate authorities to put suitable adaptive measures. In fact, this could be seen as a barrier that will be encountered while working on this project.

This project purpose is answering the core questions concerning the main impacts of climate change on water resources and how to achieve a safe level of sustainability. Water is the main source of life and this sentence has more meaning in least developed countries like in West Africa. Water is a scarce resource and this is greatly felt West Africa where it suffers from under management. This under management is noticed through diseases, lack of potable water for everyday activities, and the rapid increase in pollution rates.

ACKNOWLEDGEMENTS

***Mentor*:** Thomas Peterson
***Affiliation*:** Energy Policy and Climate Class Professor: Adaptation to Climate Change; President and Founder of Center for Climate Strategies (CCS)

TABLE OF CONTENTS

LIST OF FIGURES

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INTRODUCTION

Climate change is affecting everyone, but it affects the poorest first and more severely, predominately in Africa. In fact, in terms of climatic regimes across the African continent, the climate varies from seasonally arid tropical to humid across the equatorial regions and it is making the discussions about climate change in Africa difficult and the assessments including the adaptation strategies challenging. Global warming and climate change are being recognized as a worldwide danger to the health and survival of humans, other species and natural systems. Most West African countries suffer from their vulnerable wetlands and the natural and human-induced activities. Climate change mostly in areas subject to human activities such as agricultural drainage, watersheds, impoundments (dams, or any other structure that has the purpose of raising the level of the water of a water body above its natural level) are creating challenging situations and management in countries along the west coast of this vast continent.

This paper presents some background information on climate change, the circumstances, including the risks and vulnerabilities, and challenges in water management experienced, a detailed assessment of their adaptation strategies and finally propose a set response strategies to increase the resiliency of West Africa. In that context, a closer look will be given to particular countries, predominately in 2 focus cases: Senegal and Sierra Leone. The choice of these countries was based on many factors. First, many pieces of evidence of climate change were noticed in these regions, notably in their water management and their resilience to impacts of climate change, such as events and future projections. In fact as of a few years ago, about a third of all nations in the world is suffering and will continue to suffer from the unavailability of clean potable

water, but countries in the Sub-Saharan regions of Africa, including West Africa, shelter the largest number of countries.

Another factor that impacted the choice of these cases was the amount and the accuracy of data collected for a proper assessment of the countries environment conditions. In fact, it is a known fact that Africa is a rather poor continent, lacking the level of technology, economic health, development and management of the rest of the world. This makes it difficult to international and national authorities to record and assess data and relevant, important information. These countries were areas where organizations such as the World Bank group, the United Nations Foundation, and others have focused their work. Also, another factor included their locations and how they are situated along the shore of the Atlantic Ocean, thus having vulnerable wetlands and coastal areas.

The project starts with a general outline of western African countries statuses, followed by an overview of existing circumstances and capacities as well as gaps related to the availability and use of climate information, the easy access and availability to information, disposal of communication, framework infrastructure and other important issues connected to the efficient use of information in the context of adaptation to climate change. The project paints a clear picture of the effects of climate change on countries chosen for a particular reason and then provides a detail assessment of the risks and vulnerabilities of the focus areas, the availability and the effective utilization of tools for analysis, such as climate impact structure and models and the existing ability for adaptation strategies, which includes access to response actions, as well as training opportunities locally and the involvement of external parties. The project will then focus further on rather current and expected climate change, the diversity and their influence on

key relevant high impact sectors such as water and food security, health, energy and economy. Different factors are increasing the vulnerability and their interaction with various climatic components. The project final product is to explore current, as well as previous existing opportunities and initiative used to fight climate change impact on water resources and to provide addition adaptive aptitude though proposed projects adaptive measures with the role of reducing and limiting the overall vulnerability of the water system in West Africa.

I- General Overview: West Africa Background

The vast continent of Africa is somehow divided into different regions: North Africa, West and East Africa, Central Africa and South Africa (which is an actual country).These regions are sharing similarities either in their languages, cultures, their independence periods, and their governmental structure. This division is mainly the result of the fact that many of these countries were either part of the same colonies in the early years or migration of one area to another. The case of West Africa is about the same, except being part of the territories, as some were part of the French colonies and others, English. West Africa is composed of a diverse culture and the countries are Benin, Nigeria, Cote D'Ivoire, Liberia, Cape Verde, Niger, Burkina Faso, Ghana, Algeria, Togo, Senegal, Sierra Leone, and Mali among others. Broadly defined, West Africa occupies approximately 6 million km^2 according to the Food and Agriculture Organizational of United Nations Corporate Document Repository, Chapter 1[1].

One of the crucial key challenges regarding a changing climate in Africa is its overall influence on the sustainability of rural water supplies. Out of the West Africa's 900 million people, roughly 60% are living in rural areas and most, possibly 80%, depend on groundwater based community for household supplies for domestic and other water needs (JMP, 2008). Understanding the impacts of climate change on groundwater resources is very critical and important, yet is often ignored in development documents, debates and conferences including those on water supply and management[2]. Most West

[1] Retrieved from Fao.org,. 'Integrating Crops And Livestock In West Africa', 2015. Web. 3 May 2015. "which, with an area of 6 million km2" Retrieved from http://www.fao.org/docrep/004/x6543e/x6543e01.htm

[2] "What will climate change mean for groundwater supply in ... (n.d.). Retrieved from http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/

African countries are covered by two or three major ecological regions and the design of climate change adaptation strategies is obligated to consider the socio and environmental conditions of these three major regions. In fact past models that connect economic, social, human, and ecological systems have been hypothesized to simplify the analysis of the risks, vulnerability and resilience.

Africa is gifted with vast renewable natural resources including water resources. But their natural occurrences, such as rainfall patterns and variability, and human activities and dynamics (population growth, conflicts, pollution) keep threatening the sustainability of these resources; making the lives of the population harder. It is generally recognized that a radical change in strategies is required in order to address effectively these threats.

A- Climate Change: Why is Africa at Risk?

The African continent, particularly West Africa is, for the most part, vulnerable to hostile changes in the climate and the evidence is becoming more and more transparent. Africa has experienced huge shifts in climate over the years. Through a profound analysis conducted since the 80s by The African Studies Centre (ASC) in Leiden, The Netherlands[3], the findings on climate change are diverse. In fact the research results explained the fact that aside from climate change, many key levels such as local, regional and national levels, climate variability is most problematic for the population. Rainfall variability, which was defined in the research as the average deviation from the mean, is massive, ranged from 40 to 80% and continues to increase with a declining total annual rainfall, according to the research findings.

[3] Retrieved from Rtcc.org,. 'Responding To Climate Change 2007 - Africa - The African Studies Centre - Leiden'. Web. 2015.

The research findings also include a big change of climate in the in the marginal areas. In fact, some areas of West Africa are covered by the Sahara desert, the Sahel and the sub-humid region of Sudan. These areas are dominated by a rather threatening declining rate of rainfall that in turn poses a big menace to food security and water availability. The huge variability and unpredictable climate plus "intra-season drought"[4] has led many yearly food crises in these zones. This factor makes the population living in the rural areas more vulnerable to food and water shortages. It is frightening how these trends continue to aggregate, and it is having clear unforeseen impacts on the social and economic landscape of West Africa.

In West Africa, agriculture is related to the amount of rainfall per year. This amount of rainfall is decreasing rapidly and is moving from the northern to the southern coast and the desert. There is a vast variety in the seasons and the amount of rainfall annually.

The Intergovernmental Panel on Climate Change (IPCC) has provided analysis on the climate change future trends. In fact, according to the IPCC, at the African and global level, temperatures and sea levels are constantly rising, and there are significant changes in the level and variability of rainfall. These could generate new risks and challenges for West Africa. The temperature is changing. The impact on society and human lives is less individual based on projections. The rainy seasons in West Africa are sensitive to the variations in the global temperature. Furthermore, to add to these global occurrences, the monsoon of the west coastal areas of Africa are being impacted by different practices on the surface such as soil moisture, the ecosystem, water cycle.

[4] Retrieved from Rtcc.org,. 'Responding To Climate Change 2007 - Africa - The African Studies Centre - Leiden'. Web. 2015.

The scientific basis for the West African climate is progressively establishing a correlation between the evidence and the actual physical impacts (rising sea levels or changes in the amount of rainfall per year). Climate change trends based on projections for West Africa are not adequately trustworthy or dependable. There is evidence of complications and uncertainty while conducting scientific measurements of the future effects of climate change on a specific area and this makes the analysis of these results quite difficult.

B- Status and availability of climate data

1- Methods and Tools

Many African countries store their weather and climate information and data at the National Meteorological and Hydrological Services, or NMHSs. Other institutions such as Climate Prediction and Applications Centre (ICPAC), African Centre of Meteorological Applications for Development (ACMAD), Southern African Development Community-Climate Services Centre (SADC-CSC), AGRHYMET Regional Centre, among others are common storage using climate databases[5]. Countries that have the ability and the necessary technology and facilities to gather, analyze climate data, store their climate information in database management systems such as CLIDATA, CLIMSOFT (Zimbabwe-Guinea-Kenya-Metoffice), CLISYS (Meteo France-MFI), and CLIWARE (Russian Federation)[6]. Most countries do not make their data available easily to users due to misuse and misunderstandings. Another key challenge in restoring and

[5] Retrieved from *Assessment of Africa's Climatic Records And Recording Networks Including Strategic For Rescuing Of Climatic Data*. 1st ed. United Nations Economic Commission for Africa African Climate Policy Centre. Web. 2015. http://www.uneca.org/sites/default/files/publications/wp3-climate_data_network_and_rescuing_draft_final.pdf

[6] Retrieved from, Kontongomde, Hama. *WMO Climate Data Management Coordination Including Regional Level Aspects*. 2nd ed. 2015. Web. 3 May 2015. http://www.omm.urv.cat/MEDARE/docs/2workshop/1_WMO%20Kontongomde%20Nicosia.pdf

accessing the climate data is keeping the systems working when staff members do not take their job seriously or quit for a better-paid job.

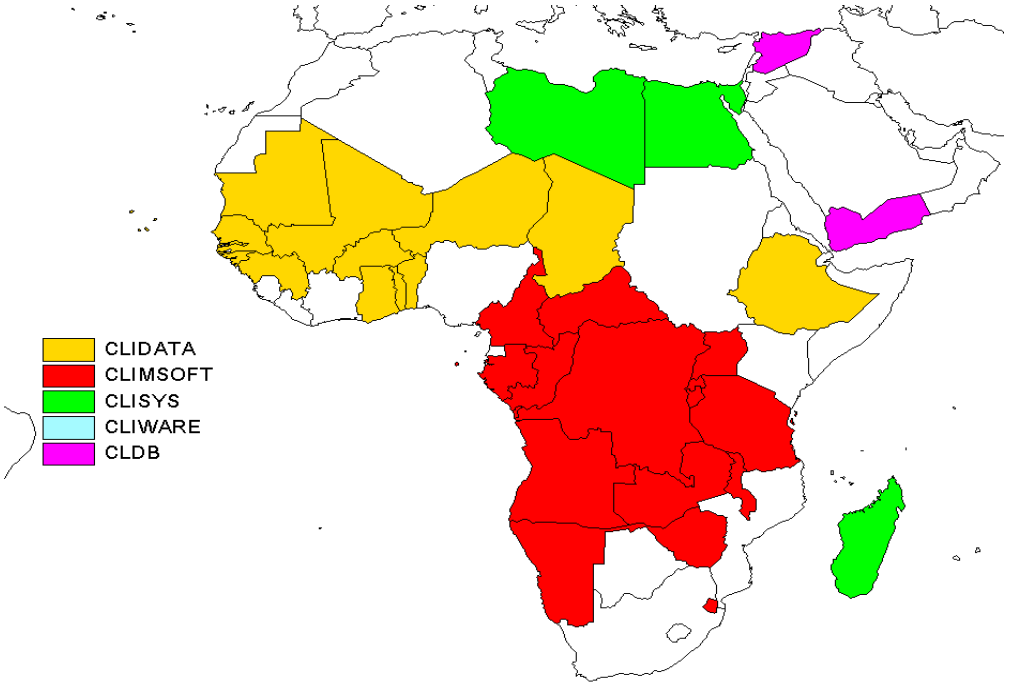

Figure 1: Developing Countries in the West African community using WMO Database Software.[7]
Source: http://www.omm.urv.cat/MEDARE/docs/2workshop/1_WMO%20Kontongomde%20Nicosia.pdf

Fortunately, a few other countries understood the importance of gathering climate and weather data in order to foresee future impacts and acquire outside help to support their economic development. A number of countries in Africa started rescuing some of their data and therefore improving their databases. In fact, many countries in the world are using thes software. For example, Figure 1 shows a few countries in West Africa,

[7] Retrieved from, Kontongomde, Hama. *WMO Climate Data Management Coordination Including Regional Level Aspects*. 2nd ed. 2015. Web. 3 May 2015. http://www.omm.urv.cat/MEDARE/docs/2workshop/1_WMO%20Kontongomde%20Nicosia.pdf

Libya, Egypt and most of the southern African countries are using CLIMSOFT that are using the software for their climate data management system.

2- Data needs

Some other countries in the world (such as India and Indonesia) currently use CLISYS database. This map (Figure 1) shows here that are also some other African countries that do not have any climate data management system. This means that although these countries have their own climate data management, maintaining and accessing these data is a significant issue. Furthermore, acquiring relevant data for the purpose of water data management is a key challenge that makes it harder to assess the impacts of climate change.

C- The Importance of Water Management

Water is the most fundamental need of human life. According to the Water Information Program: Providing Water information to the communities of southwest Colorado, our bodies are about 60 percent water and blood is 92 percent water, the brain and muscles are 75 percent water, and bones are about 22 percent water[8]. In fact, according the facts, a human body can survive without food for a month or more, but only about a week without drinking water[9]. Bottom of line is water is life, and there is no life without water. We need clean, sufficient water in order. The growing stress on water resources is from any factors such as population, economic growth, pollution and the major one is climate change. Water management is crucial for human lives, safety, and

[8] Water Facts | The Water Information Program. (n.d.). Retrieved from http://www.waterinfo.org/resources/water-facts

[9] Retrieved from http://www.waterinfo.org/resources/water-facts

future development. It is also a critical factor in a nation's commercial, industrial and most of all economic development.

In countries such as Sierra Leone, Algeria, Morocco, Senegal, or Mauritania, the water sector is suffering from shortages and extreme migration to neighboring countries due to inadequate water management. One prominent issue is the accessibility of data. The access to available data to predict near future events that could become more disastrous than projected is a challenge that needs to be assessed. In fact, as development is a significant issue in those countries, their adaptive capacity or resilience to extreme events is relatively low comparing to developing countries. Accessing water is and will become more important for agriculture especially when their farmers and their businesses include irrigated farms. The tendency to reduce water sanitation and pollution problems and also adopting adaptation strategies has also been one of the drivers towards improving water resources management.

Water is important, from drinking it to the energy source. For humans, animals and nature, we need to improve water quality. To do so many governments in West Africa have reached out to outside help, notably from international organizations and developed countries (United States, China, Germany) and have set national and international requirements and measures for surface, drinking and ground water management. Even the disposal of wastewater has set requirements and standards before its reuse.

II- Climate Change Impacts: The Water Sector

A- Business as Usual

1- Food Security and Agricultural Production

Over the past decades, climate change has been affecting the access to food and water in significant but highly uncertain ways. There is strong evidence of the fact that the consequences of these changes will be developing countries. The main reason is mostly that of the high vulnerabilities levels, high exposure levels, the high poverty rates and finally, the low adaptation capacities. Moreover, as climate change keeps affecting the developing countries, the population, mostly rural, who is widely dependent on agriculture for income, food production and employment will be more affected. The temperatures are already higher than usual, and according to the IPCC AR4 Assessment Report on Africa Chapter 9, "Projected reductions in yield in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers being the most affected"[10].

For years, climate change reports have assessed a severe impact on food production, security, and availability, mostly due to rather relatively small increase in the temperature and changes in the climate. As the majority of the rural population lives and depends entirely on rain-fed activities such as agriculture, this population is most vulnerable and at very high risk of severe droughts and high-risk floods. The poverty rates are and will continue to increase and get more challenging. Crop yields and ecosystem will be intensely affected by climate change impacts and the poorest population in sub-Saharan Africa, who are prone to extreme weather events, suffer the most because they have little to no capacity to adapt to climate change by either improved seeds or unconventional livelihoods.

[10]Retrieved from Githeko, Andrew et al. *Africa*. 1st ed. IPCC. Web. 2015. https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter9.pdf

In sum, the fact that the agricultural and rural sector on which the population of West Africa depends for income and food production, makes the region definitely at risk of adverse impacts of climate change and the inevitable increase in climate variability. The same projections from the IPCC AR4 Report on Africa show that a general increase in temperatures for West Africa predicts an increase in precipitation variability and frequencies of extreme weather and events.

2- Social impacts: conflicts, crisis and migration of population

Environmental changes, either due to human activities or natural occurrences, have been a key driver of population migrating in West Africa. West Africa and migration have been historically a challenge, regionally, nationally and internationally. As urbanization and rather rapid growth of states, combined with the search for better agricultural lands, commercial trades, demand for employment, industrial production, armed conflict, land degradation due to extreme drought events such as in countries like Morocco and Algeria and finally rural poverty; conflicts and migration has played a vital role in economy and development patterns in the region (DFID 2004). In the IPCC AR4 report on Africa, Chapter 9, projections of a sea-level rise in this century are less than one meter, not including the melting of ice sheets. When the ice sheets melts are included into the dynamics, the IPCC projects about two meters of sea level rise. And as we know, even a one-meter rise would displace more than 145 million people and would contaminate drinking water and agricultural land for tens of millions more[11].

[11]How Climate Change Threatens Food Security - Climate & Capitalism. (n.d.). Retrieved from http://climateandcapitalism.com/2009/01/22/how-climate-change-threatens-food-sec

According to Arthur H. Westing et al., [12] the environmental challenges encountered have been recognized as being the source of national and regional disputes, which in turn lead to armed conflicts. These conflicts are either about access to resources, disease epidemics that devastate the ability of a particular community or the impacts of the migrants on society and the economy. These causes are particularly relevant to countries in West Africa due to the increase of refugees by the environment. One example is the ongoing Niger Delta crisis since the 90s, between foreign oil corporations and Niger Delta's minority ethnic groups who feel they are being exploited[13].

West African migration patterns have changed in the past few years and research shows that they depend on the availability of local natural resources which appear to be fragile and low on the global market. These migrations are becoming part of West Africa's dynamics that becomes a challenge for the economic and immigration policies. According to the Economic Community of West African States (ECOWAS)[14], human insecurities has grown considerably over the past decades, which, of course, needed their involvement to its effects on sub-regional economic. In fact, ECOWAS has been an influence and intervening in many political crisis. Together with political development, changes in climate and its impact on the environment play a big role in migration. Also, with this in mind, early evidence of extreme droughts and desertification in West Africa

[12] Retrieved from Westing, H. A., Fox, W., and Renner, M., "Environmental Degradation as both Consequence and Cause of armed conflict. Working Paper prepared for Nobel Peace Laureate Forum Participants by PREPCOM subcommittee on Environment Degradation. ftp://ftp.fao.org/docrep/fao/010/a0701e/a0701e08.pdf

[13] Retrieved from Armed Conflict," Working paper prepared for Nobel Peace Laureate Forum participants by PREPCOM subcommittee on Environmental Degradation, June 2001. http://www.institute-fornonviolence.com.au/downloads/pdf/EnvirDegrad.pdf; page 5 of 16.

[14] Retrieved from Yaro, Dr. Joseph A. *Migration In West Africa: Patterns, Issues And Challenges*. 1st ed. Legon: Centre for Migration Studies University of Ghana, Legon, 2015. Web. 2015. http://waifem-cbp.org/v2/dloads/MIGRATION%20IN%20WEST%20AFRICA%20PATTERNS.pdf

show that with an increase of population combined with the stress on natural resources availability and use, conflicts in regions of West Africa between migrants and residing communities puts a burden on water resources.

3- Economic Impacts

The economy is a rather vulnerable sector when it comes to climate change, mainly because it affects the supply and demand for food, water, livelihood goods and services. There is also clear evidence that the intense migration of population, the change in precipitations variability and extreme events are taking a toll on the demand for commodities by increasing it but also taking a bigger toll on supply as agricultural yields are affected by floods and droughts. In fact, current and future climate change impacts could have a negative influence water demand and, of course, on agricultural irrigation demand, production, and jobs. This in turn implies no jobs no money for the economy.

4- Health Impacts

West Africa is one of the most vulnerable continents to climate change impacts. The low adaptive capacity, the low economic and development level of the continent make the impacts of climate change worst. Population's health is already at risk due to other factors but the adverse impacts of climate change and variability, especially in relation to water resources management are increasing the risks for diseases such as malaria, and typhoid due to increased precipitations. Other waterborne diseases include eye diseases (cataracts) are reported in the arid and semi-arid regions of Africa due to "low cloud

cover and greater intensity of solar radiation and cholera and dysentery due to urban flooding and improper disposal of wastes"[15].

Figure 2: SIERRA LEONE: Rampant disease washes in with flood water.
Source: http://www.irinnews.org/report/79358/sierra-leone-rampant-disease-washes-in-with-flood-water

In addition, other climate conditions with warmer and more humid areas, there is evidence of bacteria and mold. Moreover, there is evidence of a large number of people whose health has been impacted and the main causes is that malnutrition and water scarcity are and could be the most important health risks of climate change (Bates et al., 2008)[16]. The World Health Organization (WHO) points out that having poor health increases vulnerability and decreases the adaptive capacity of communities. According to

[15] Retrieved from Urama, Kevin Chika, and Nicholas Ozor. *IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES IN AFRICA: The Role Of Adaptation*. 1st ed. African Technology Policy Studies Network (ATPS), 2010. Web. 2015. http://www.ourplanet.com/climate-adaptation/Urama_Ozorv.pdf

[16] Retrieved from Bates, B.C., Kundzewicz, Z.W., Wu, S., and Palutikof, J.P. (eds) (2008) Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change. IPCC Secretariat, Geneva: 210pp

WHO and UNICEF Joint Monitoring Programme, their estimate is that 1.1 billion people, which is about 17% of the global population, will not have access to water resources[17].

B- Water Metrics: Observed Variability

Water is what connects the changes in atmospheric temperature and physical systems. What started it is the global warming of the planet, including atmosphere and oceans. These patterns of rainfall have the consequences of flooding, runoff, and surface and groundwater storage, changing the flow of rivers and with greater chances of extreme droughts in different areas of Africa. In turn, human lives, systems and those dependent on direct access to water will be.

Sectors dependent on water supplies and precipitation such as agriculture, human patterns, sanitations, and irrigation are being affected by the alterations in rainfall. These patterns are leading to changes in human health, wealth and security. In addition, as rainfall becomes rare, population keeps growing, and their income levels are changing. Their demand for water resources is also changing. Water is an essential resource for sustaining economic development in all sectors. Fresh, clean water is a necessary input for industry, power and electricity generation, tourism, agriculture, fisheries and livestock production. These activities are essential to lives and well-being of the population. These factors are the sources of employment and contribute to the economy.

Safe water is an economic and social good. The supply of water and its controlled sanitation are the crucial constituents and metrics to consider for a healthy and successful

[17] Retrieved from World Health Organization, WHO/World Water Day (2001) Too little Water: Floods and Droughts. World Health Organization. http://www.who.int/water_sanitation_health/hygiene/emergencies/floodrought/en/index2.html

nation. The acquisition and delivery of safe drinking water and suitable sanitation amenities the highly demanding population can, in turn, reduce the prominence of water-borne diseases, such as cholera, diarrhea, and malaria.

1- Changes in precipitation: flooding and drought patterns

The impacts of climate change on water sector can be separated roughly into how certain and uncertain the future is. In fact, even though there is large certainty on the how climate change is impacting and will impact the ecological system temperature, precipitation, and evapotranspiration, it is less and less certain about the impact on runoff and river flows, flooding and drought patterns. The reason for this is because of the number of people and how much human activity is affecting the patterns at a more local scale.

According to the Special Report on Emission Scenarios (SRES)[18], forecasts based on scenarios show a rise in the global average surface temperature of approximately 1 degree by the year 2020. The temperature rise is associated with an anticipated increase in precipitation at higher latitudes.

[18]Retrieved from Arnell, Nigel W. *Climate Change And Global Water Resources: SRES Emissions And Socio-Economic Scenarios*. School of Geography, University of Southampton, Southampton, 2015. Web. 2015. Global Environmental Change 14. http://life.bio.sunysb.edu/~spgp/2004_03_09/climate%20change%20and%20global%20water%20resources-Global%20Environmental%20Change.pdf

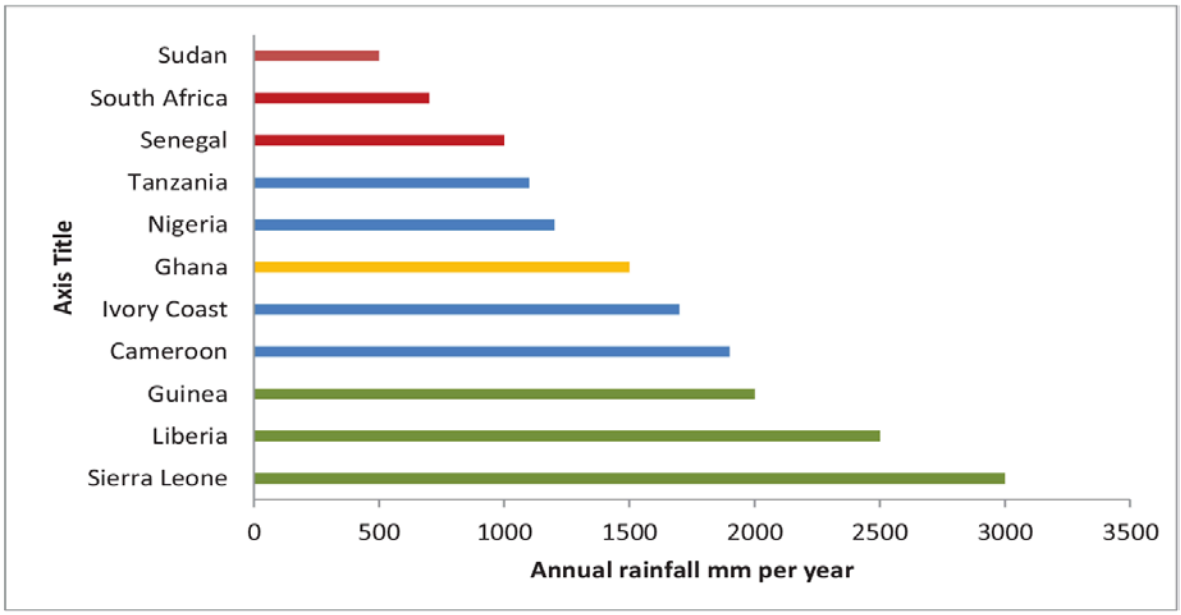

Figure 3: Annual rainfall per year African Country
Source: http://www.grin.com/en/e-book/230290/prospect-of-bio-fuels-in-sierra-leone

Figure 3 represents an overall regional climate projection of annual rainfall per year for West Africa. As shown in the table, some countries like Sudan are suffering from a shortage of rainfall while others like Liberia and Sierra Leone are receiving plenty of precipitation. It shows how some countries are on the verge of total drought and others on the verge of extreme flood events. Many other studies on climate change in West African countries connect the changes in precipitation patterns with increasing flooding events.

2- *Changes in demand by sectors and regions*

West African countries, especially countries part of ECOWAS (Economic Community Of West African States) are struggling with the stress that climate change puts on water resources. Climate change and precipitation variability are very likely to inflict additional stress and burden on the availability, accessibility and demand in West Africa. As the population keeps growing, either from migration or high birth rates, demand for clean drinking water keeps growing. In the health sectors, water sanitation is

the main issue. It is, in fact, the primary driver of public health. The prominence of flooding events is more likely to increase the probability of waterborne diseases. As the diseases spread, it becomes harder to treat and contain. On the treatment side, the development of vaccines and medicines requires a tremendous amount of water resources available. The worsening of water quality and quantity may also be the result of a variety of human activities, ranging from economic, agricultural production to personal use.

The consequences are moving towards the reduction of available fresh water, and impacts on sea living systems. According to a World Bank report on Water Resources Management: Sector Results Profile, Water Resources Management in a Changing Climate, population access to safe and clean water is still very small, "out of reach for 2.5 billion and 768 million people respectively, leading to thousands of lives lost daily and billions of dollars in economic losses annually". Plenty and sufficient evidence have shown that climate change is a worsening issue with more rainfall variability, resulting in more frequent and extreme droughts and floods events. According to the same World Bank report, an estimate of 43 to 50 percent of the global population will suffer from water scarcity by 2080, compared to 28 percent today.[19]

III- West African Countries and Climate: Focus Cases and Adaptation Actions

Climate change has been harsh many poor countries. Some of them are conscious of the impacts and with outside help are adapting and surviving. Some countries are still

[19]Retrieved from Huffman, Edwin. 'Water Resources Management: Sector Results Profile'. *Worldbank.org*. N.p., 2014. Web. 2015. http://www.worldbank.org/en/results/2013/04/15/water-resources-management-results-profile

at the mercy of the hard effects of climate change and having more difficult time recovering and adapting to future impacts. Two focus case studies, Sierra Leone and Senegal, will emphasize on the effect of changing precipitation rates, annual rainfall decline and extreme drought on water management, on the current adaptive capacity and the adaptation measures of these countries. It will also show that these two countries have been at the mercy of climate change and struggling with water management. The analysis of the risks and vulnerabilities in relation with water management of these will help identify current adaptive measures these countries possess and shape up potential adaptation strategies to improve their water resource management.

A- SIERRA LEONE

Figure 4: Sierra Leone Location in West Africa[20].
Source: http://kids.britannica.com/comptons/art-166021/Sierra-Leone

[20] Retrieved from http://kids.britannica.com/comptons/art-166021/Sierra-Leone

Sierra Leone is a small country situated on the west coast of West Africa, precisely, on the southeast side of the Republic of Liberia to the north of the Republic of Guinea (Figure 4). Sierra Leone western borders are alongside the Atlantic Ocean. Freetown is the capital, the economic and political center. Its second major commercial center is Bo. The country is divided into 14 districts and is characterized by its highlands, lowland and coastal plains, hills, and mountains. The country has a wealth of many natural resources. Sierra Leone population is mostly rural and according to the World Bank, about 80-90% of the 6.1 million inhabitants reside in rural areas and the population income depends mostly on natural resources[21].

The nation's income is mostly covered by agriculture, which is the largest sector of the economy, about 35-47% of GDP according to the Word Bank and is the leading provider of jobs and food the population. Despite its large agricultural sector, the country is suffering from inadequate infrastructure, low capacity, unemployment, high maternal and infant mortality, widespread rural poverty, the impact of the global financial crisis, and gaps in financial management and governance, according to the World Bank[22].

In fact, the majority of the population is in rural areas but lives in the state of poverty. In fact, the World Bank explains that Sierra Leone is ranked 183 out of 187

[21]Retrieved from The World Bank. 'Sierra Leone: Dashboard'. N.p., 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SLE&ThisTab=Dashboard

[22] Retrieved from The World Bank. 'Sierra Leone: Dashboard'. N.p., 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SLE&ThisTab=Dashboard

countries in the 2014 United Nations Development Programme Human Development Report, hence is considered a low human category country[23].

Climate change is threatening food security and the lives of the majority of Sierra Leone's population. The impacts are already being felt in the country through many seasonal droughts, thunderstorms, very hard and strong winds, floods, and precipitations patterns. In fact, as reported in Sierra Leone's National Adaptation Programme of Action (NAPA)[24], Sierra Leone has been placed at the bottom of UNDP's Human Development Index (HDI) regardless of how rich in resources the country is. Also, poor communities are currently the ones suffering the most from climate change effects with crop damage and water shortages in some areas of the country.

- ***Climate Change Trends: Risks assessment and vulnerabilities***

Sierra Leone's sea level keeps rising and is threatening the coastal regions such as the vulnerable communities of Kroo Bay and Moa Wharf[25]. In fact, according to the World Bank, there have been events of increased flood on the coastal areas, including erosions and, above all, the reduction of the quality fresh water. These events have provoked population displacement, many property losses. Also, groundwater resources are decreasing and making agriculture activities very difficult on the coastal areas. The changes in precipitation patterns include extreme floods, rainfall disruptions and

[23] Retrieved from The World Bank. 'Sierra Leone: Dashboard'. N.p., 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SLE&ThisTab=Dashboard

[24] Retrieved from *National Adaptation Programme Of Action (NAPA)*. 1st ed. UNDP, 2007. Web. 2015. http://www.undp-alm.org/sites/default/files/downloads/sierra_leone_napa.pdf

[25]The World Bank,. 'SIERRA LEONE: Natural Hazards'. N.p., 2015. Web. 2015. Retrieved from http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SLE&ThisTab=NaturalHazards

droughts, and these are having harmful impacts on human health, mainly by increasing their risks to diseases such as diarrhea and cholera.

In Sierra Leone, floods usually happen during the rainy seasons mostly from storm surges and dense precipitations. Sierra Leone is most vulnerable on agriculture as the activities are slowing either due to rare precipitations, in the northern regions. The patterns are having a big impact on agricultural and food production, commercial and residential infrastructure, human and ecosystem health, biodiversity along the coast. Furthermore, the global mean level of the sea is increasing at an accelerating rate. As coastal regions keep experiencing an increase in the sea level more frequently, the population has been experiencing a decrease in food security, access to clean and potable water, which makes it difficult to care for families, and at risk for water-borne diseases such as anemia, cholera, malaria, typhoid, etc.

Moreover, Sierra Leone is characterized by its tropical climate, with its distinctive wet and dry season. The rainfall changes are happening on an inter-annual and inter-decadal level. According to the World Bank Report on Sierra Leone Natural Hazards[26], the wet season starts from May to October, with more precipitation in July and September, and the dry period follows from November to April. The World Bank estimates the mean annual rainfall for the country around 3,000 mm, and the coastal and the south around 3,000 to 5,000 mm annually.

[26]Retrieved from The World Bank, 'SIERRA LEONE: Natural Hazards'. N.p., 2015. Web. 2015. Retrieved from http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SLE&ThisTab=NaturalHazards

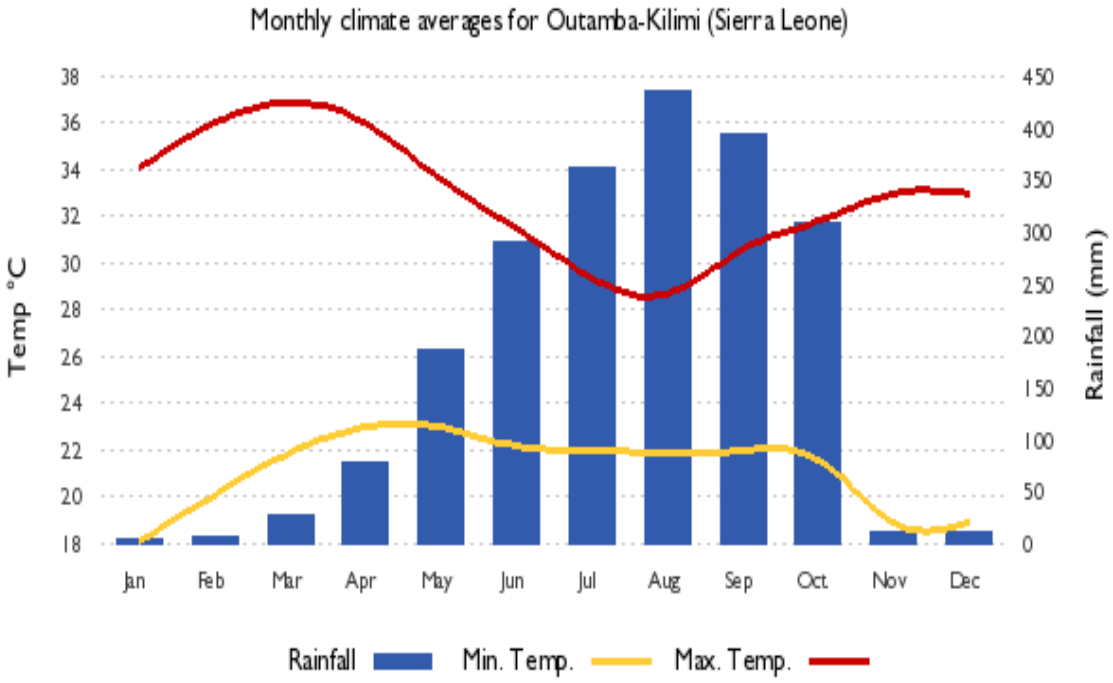

Figure 5: Monthly Climate averages for Outamba-Kilimi in northwest Sierra Leone.[27]
Source: http://bioval.jrc.ec.europa.eu/PA/pa/7417/PA_report_7417.html

Also in the northwest of Sierra Leone, in the Outamba-Kilimi region (Figure 5), rainfall variations are very extremes, with about 0 to 10mm of rainfall from November to February to a sudden rapid increase if precipitation from May to October (26mm to about 37mm). This trend is also characterized by very high temperatures during the dry months and lower ones during the heavy rain periods.

According to Sierra Leone's National Adaptation Programme of Action (NAPA) as mentioned earlier, Sierra Leone's economy rely mostly on its natural resources, thus making the country particularly vulnerable to climate change. NAPA also anticipated effects on its agriculture, food Security, water resources, forests and natural resources and

[27] Retrieved from *Overview Of Outamba-Kilimi*. 1st ed. European Communities, 2009. Web. 2015. http://bioval.jrc.ec.europa.eu/PA/pa/7417/PA_report_7417.html

human health sectors. For example, the World Bank study on Sierra Leone's climate impact explained that there have been cholera occurrences that have been linked to heavy rainfall in West African countries and these outbreaks are very likely to increase as precipitations in the regions are projected to increase.

- ***Future Trends***

Future trends in Sierra Leone project a rise of the average annual temperature between 1.0° C and 2.6° C by in the next 60 years, according to the World Bank[28]. The GCM, Global Circulation Models, also forecasts an increase in the mean annual rainfall in the country, especially during July to September and October and December. It also predicts that by the end of the 21st century, the precipitations in the regions of West Africa will increase with a small delay to the start of the rainy season[29]. But then again, the same study from the World Bank on Sierra Leone confirms that the confidence level in the GCM projections is low to medium range for heavy rainfall in West Africa by the end of the 21st Century. In addition, the sea level is projected to rise during the 21st century and increase by 0.4 m (low emissions scenario) to 0.7 m (high emissions scenario) by 2100[30].

- ***Current Adaptive measures***

[28]Retrieved from The World Bank, 'SIERRA LEONE: Climate Portal, 2015. Web. 2015. Retrieved from http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SLE&ThisTab=NaturalHazards.
[29]Retrieved from The World Bank, 'SIERRA LEONE: Climate Portal, 2015. Web. 2015. Retrieved from http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SLE&ThisTab=NaturalHazards.
[30]Retrieved from The World Bank, 'SIERRA LEONE: Climate Portal, 2015. Web. 2015. Retrieved from http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SLE&ThisTab=NaturalHazards.

Some of the necessary adaptation strategies in Sierra Leone have the objective to improve the sanitation of the ground water, reconstruct its coastal defense systems, develop a sea level rise monitoring system, increase access to safe and clean water to the most vulnerable population, and develop a way to prevent, and maybe, limit the impacts of climate change by providing potential early warning for extreme weather events. Currently, a few projects have been put in place to aim to reduce the potential vulnerability and risks created by floods and droughts to the population and infrastructure. The projects are Waves for Water: Project Sierra Leone which end goal is to bring "100 clean-water systems, each giving access to safe drinking water to over a hundred people for many years to come"[31]. This project aims to provide many filters to help increase the availability of potable water, with each filter delivering up to one million gallons of cleaner water. One other prominent project is Sierra Leone's Rural Water Supply and Sanitation Project which funded was recently approved by the African Development Bank (AfDB) Group in 2013, in Tunis. In fact, US $43.27 million (UA 28.845 million) was awarded to finance the project. The project is aiming improve and sustain the access to clean water, increase of basic sanitation and "develop a comprehensive national framework for rural water supply and sanitation investments"[32]. The WaterProject is another project developed in Sierra Leone that also is trying to help the country adapt to the current and future impacts of climate change on water resources.

B- SENEGAL

[31] Retrieved from Waves For Water, 'Project Sierra Leone', 2013. Web. 2015. http://www.wavesforwater.org/project/sierra-leone

[32] Retrieved from Afdb.org, 'Afdb Approves US $43.27 Million for Sierra Leone'S Rural Water Supply And Sanitation Project - African Development Bank', 2013. Web. 2015. http://www.afdb.org/en/news-and-events/article/afdb-approves-us-43-27-million-for-sierra-leones-rural-water-supply-and-sanitation-project-12310/

Figure 6: Senegal Location in West Africa.
Source: http://kids.britannica.com/comptons/art-166028/Senegal

Senegal is small country located on the west coast of Africa, and that has borders with the Atlantic Ocean. Its neighboring countries are Mauritania and Mali at the north borders, Guinea, and Guinea-Bissau at the east borders, and to the south, it almost surrounds Gambia.

Senegal's capital is Dakar. According to the World Bank report on Senegal, the UN Development Programme's (UNDP) has ranked Senegal 156th out of 177 countries in the human poverty index. In Senegal, poverty is a significant issue especially in rural areas, housing about 60% of the population the other 40% in urban areas[33].

- ***Climate Change Trends and Risk assessment and vulnerabilities***

[33]Retrieved from The World Bank, 'SENEGAL: Dashboard', 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SEN&ThisTab=Dashboard

In regards to its climate, Senegal is characterized by its two distinct seasons. According to the World Bank database on Senegal's Climate Change, Senegal has a dry season from around October to May and a rainy season from June to September[34]. The country is located in a region that makes it more vulnerable to drought, flooding, and the population is more prone to health epidemics due to sea level rise and coastal erosion and fires.

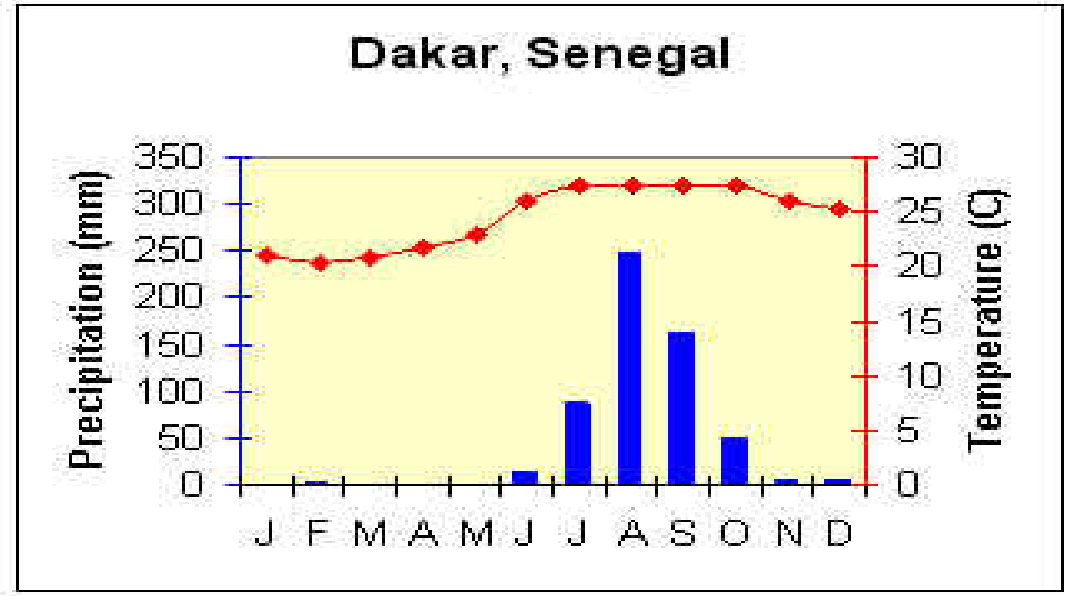

Figure 7: Climograph for Dakar.
Source: http://www.earthonlinemedia.com/ebooks/tpe_3e/climate_systems/tropical_wetdry_1.html

According to the Physical Environment: Tropical Wet/Dry (Savanna) Climate, the city of Dakar is located at a higher altitude, which makes it more prone to a higher temperature[35]. Figure 7 above is a climograph made the Dakar, depicting the average temperature (in °C) together with the average precipitation (in mm) for a 12-month

[34]Retrieved from The World Bank, 'SENEGAL: Dashboard', 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SEN&ThisTab=Dashboard

[35]Retrieved from Earthonlinemedia.com, 'Wet Dry Tropical Climate', 2012. Web. 2015. http://www.earthonlinemedia.com/ebooks/tpe_3e/climate_systems/tropical_wetdry_1.html

period. In fact the mean temperature (red dotted line) has higher temperatures in very late spring, from July to the end of the year, a little above 25°C. The pattern is different for the mean precipitation, as precipitations are almost inexistent at the beginning of the year and then it becomes extremely dense, about 250mm, from July to September. The variation of the rainfall in the city is presenting evidence of extreme droughts that may have an impact on crop production.

Research and studies conducted by the World Bank show complications regarding the water infrastructure, coastal zones, and the agriculture sectors of the country. In fact, the Sahel covers parts of Senegal, notably from west to east, and its climate is characterized by a very variability of rainfall during the year. It is posing difficulties to the climate models to identify the possible precipitation trends and make accurate projections. There has also been evidence of unusual high rainfalls while in the dry season a few years ago (2000-2006)[36], but the actual estimates are uncertain and have not been consistent.

Regarding the natural hazards threatening Senegal, extreme droughts, floods, sea-level rise, and coastal erosion are first on the list. According to the World Bank, flooding events result from river overflows due to heavy rains in the middle of the year and insufficient drainage infrastructure (in Kaolack and Dakar especially)[37]. Other factors, as the World Bank explains, which make the country more vulnerable to floods, are heavy storm surges that have impacts on agriculture by introducing salt and water into the

[36]Retrieved from The World Bank, 'SENEGAL: Climate Baseline', 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SEN&ThisTab=ClimateBaseline

[37]Retrieved from The World Bank, 'SENEGAL: Natural Hazards', 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SEN&ThisTab=NaturalHazards

crops. Past events show that there have been more floods events than droughts, but the droughts have proven to have more serious impacts.

Moreover, sea level rise strength keep increasing and in turn increase the force of storm surges on the coast. The impacts are coastal erosion, putting the Senegalese population, economy, and infrastructure by threatening about 74% of households[38]. According to the World Bank Sierra Leone: Natural Hazards, "sea level could rise by up to one meter by the end of the century, and this would put at least 110,000 people, mostly in southern Senegal in the Cape Verde region, at risk of coastal flooding. Some studies, however, put the number of people at risk much higher. The higher frequency of heavy rainfall events is likely to escalate the incidence of floods, leading to possible health impacts that include the spreading of water-borne diseases such as cholera in the aftermath of floods. Available data indicates that the average number of 'hot' nights per year increased by 27 (an additional 7.3% of nights) between 1960 and 2003"[39]. This analysis shows that the risks and vulnerabilities of Senegal have been increasing for a long time with nothing to make the population more resilient.

- ***Future Trends***

Future trends projected temperature increase by the years 2060 and 2090 and also expect a faster rate of warming in cities located in central Senegal than the ones on the

[38]Retrieved from The World Bank, 'SENEGAL: Natural Hazards', 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SEN&ThisTab=NaturalHazards

[39]Retrieved from The World Bank, 'SENEGAL: Natural Hazards', 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SEN&ThisTab=NaturalHazards

coast[40]. These projections mean that there would be more "hot "days, and these are extending their reach to the south and east of the country. This means less precipitations, putting the country at serious risk of droughts, affecting agriculture, the ecosystem, and water management in terms of scarcity of water for drinking purposes. Also, sea level could rise by up to one meter, increasing the risk of coastal flooding to the population, at least 110,000 people, mostly in southern Senegal in the Cape Verde region according to the World Bank[41]. The impacts will be numerous and not without consequences, with higher strength, such as on health, with an increase of waterborne diseases outbreaks due to projected huger frequency of heavy precipitation, according to studies conducted by the World Bank Group and the partner country staff[42].

- ***Current Adaptive measures***

Adaptation strategies in Senegal are aiming at improving the economy of the country due to the severe consequences climate change inflicted on the water resources. In fact, many projects have been in process to reduce the impacts of climate change and increase the resilience of the country. The World Bank Group identified three projects that have different objectives, but they all have the same goal. These three projects include:

[40]Retrieved from The World Bank, 'SENEGAL: Natural Hazards', 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SEN&ThisTab=ClimateFuture

[41]Retrieved from The World Bank, 'SENEGAL: Natural Hazards', 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SEN&ThisTab=ClimateFuture

[42] Retrieved from http://sdwebx.worldbank.org/climateportalb/doc/GFDRRCountryProfiles/Dashboard_metadata_MFZ.pdf

- Platform for helping vulnerable communities Adapt to Climate Change[43]

The main objective of this platform is to integrate the use of scientific information and local adaptation strategies into the current Senegal policies in order to reduce its vulnerability. This

Particular project will, according to the World Bank, incorporate "an observatory of climate change, sensitize local actors, and identify and implement adaptation strategies to improve the living conditions of vulnerable populations, or at least slow down their degradation"[44]. The goal is to use the same project in other climate change vulnerable country if the project is successful.

- Climate Change Adaptation project in the Areas of Watershed Management and water retention[45]

This project has the objective to increase the resilience of the agriculture sector in relations to the impacts of climate change on the water sector. According to World Bank on Adaptation Measures for Senegal, this project is aiming at two NAPA objectives that are "water-harvesting and watershed management and water conservation and efficient irrigation". (The World Bank Group, 2015)

IV- **Recommendations: Proposed Response Actions**

A- Adaptation to Climate Change

[43]Retrieved from *Review Of Current And Planned Adaptation Action: Southern Africa*. 1st ed. Adaptation Partnership, 2011. Web. 2015. http://sdwebx.worldbank.org/climateportalb/doc/USAIDProfiles/Africa_Southern_AfricaRegional_and_Country_Profiles_Final_with_new_template.pdf#page=210

[44]Retrieved from The World Bank 'SENEGAL: Adaptation, 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SEN&ThisTab=Adaptation

[45]Retrieved from The World Bank 'SENEGAL: Adaptation, 2015. Web. 2015. http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=SEN&ThisTab=Adaptation

As explained throughout the project, climate change has been a major problem for many countries in West Africa. The increase in variation of temperatures, the inconsistent changes in precipitations in different regions have increased the vulnerabilities of countries like Sierra Leone. They become more and more sensitive to climate change and extremely prone to disastrous consequences due to increased frequency of flooding and droughts events. Africa as a whole is a poor continent, with many of its countries being ranked at the bottom of (United Nations Development Programme Human Development) UNDP report.

Moreover, the inadequate management of the water resources in West African countries takes a toll on the population, thus on its economy. The population is at risk of increased frequency of waterborne diseases outbreaks, affecting mostly children and women. The economy sector is taking its share of risks as the income and GDP of these countries is based on agriculture. Without access to clean water people die. Without access to water due to extreme drought events, crops die, causing a decline in the economy. In addition the inconsistency and unavailability of many climate and weather data that will be a great asset in providing a better assessment of rainfall variations and predict future events are another big issue. All of these show that something must be done in order to protect the country, its population and economy. Without any concrete actions, these countries and communities are endangered. A few projects have been put in action to alleviate some of the climate change impacts in these country. But more can be done because, as we know the climate is not getting any better, which means the vulnerabilities will increase and the impacts will become more disastrous.

B- Global Responsibility and Action

- ***Role of Adaptation***

Water is the only thing that connects the rise in temperatures in the atmosphere and human patterns. And climate change, by altering the natural cycle, generates a rapid warming of not only the atmosphere but also the oceans which in turn will change the weather cycle. In West Africa, the effects of the change in weather cycle are proving to be significant and concerning. Rainfall patterns are changing, and the main consequences are the likelihood of extreme weather events such as floods and droughts. Since climate change has become recognized as a real problem, scientists and policy maker all around the world have committed their time, money and resources to the issue. Local, national and international policies also have devote substantial attention and assets to providing first-hand response actions in helping limit the impacts of climate change by focusing on mitigating the emissions of greenhouse gases.

The concept of adaptation has been defined in many different ways. The Intergovernmental Panel on Climate Change defines it as being an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007). The United Nations Framework Convention on Climate Change gives the definition to adaptation as a set of actions that are taken to help the impacted communities and ecosystems to cope with changing climate condition[46]. Many years ago, the IPCC explained that adaptation offers a "very powerful option" to replying the impacts of climate change and must also be considered as a "complement" to mitigation.

[46]Retrieved from Vcccar.org.au,. 'Climate Change Adaptation Definitions', 2015. Web. 17 Apr. 2015. http://www.vcccar.org.au/climate-change-adaptation-definitions

The purpose of paper is to discuss the role of adaptation responses for small and large communities in climate change policy, to offer a set of adaptive measures in complement to the current adaptation strategies through data and information to use within the water sector. In fact, as of today, climate inconsistency and unpredictability has a larger impact than expected on water supply, demand, and resources. People affected are growing by millions every year. The problem is that the authorities working with the water sector are conscious of the disastrous impact that climate change has on water resource management but they do not know how to integrate and use the climate information into their policies and structures[47].

- ***Institution and Policy Making: Improving Water Resources Governance and Decision***

Adaptive measures can be planned in advance or spontaneously in place. These measures include short and long-term development programs to help the population that have first-hand experienced the impacts of climate change. They also include some sustainable large-scale infrastructure.

- ***Adapting to floods***

The destructive effects of flooding events are complex. Usually floods cause major infrastructure damage, such as disturbing roads, rail, airports, electricity systems, waste disposal systems and most importantly water supplies. Furthermore, the economic effects of floods are much more than shown. Indirect and direct economic losses affect more than flooded area population that are set for long term impacts.

[47]Retrieved from Ludwig, Fulco et al. *Climate Change Adaptation In The Water Sector*. 1st ed. Co-operative Programme on Water and Climate (CPWC), 2008. Web. 2015. http://www.hydrology.nl/images/docs/dutch/cpwc/Climate_Change_Adaptation_in_the_Water_Sector.pdf

Education measures could help reduce the damages inflicted on property. Pushing the authorities and population to help themselves regarding the pressure instigated by flooding are much encouraged, thus lessening a few of the impacts on people's health. These measures especially include flood proofing of properties and development of community preparedness initiatives along the lines of those widely used in the United States and Europe for hurricanes and other natural disasters.

Copenhagen, Denmark has been impacted by great flooding events in 2010 to 1011, which let the city develop a Climate Adaptation Plan in 2011 in order to address better the issue of climate change. The plan includes many green and blue designs to limit the effects on the city's infrastructure which received an INDEX: Design to Improve Award in 2013[48]. This plan is a great example that cities like Bo in Sierra Leone should refer to when it comes to adaptation to climate change.

In fact the city explains in the INDEX Award Winner: Copenhagen Unveils Comprehensive Climate Adaptation Plan to Reduce Flooding and Boost Local Economy article that the plan is meant to bring all officials to work together in order to limit expenses, create more job and increase the city resilience to flooding events[49]. The plan outlines 3 targets:

- Minimize potential damage arising from climate change;
- Improve warning and response systems to deal with abnormal conditions;

[48]Retrieved from Buczynski, Beth. 'INDEX Award Winner: Copenhagen Unveils Comprehensive Climate Adaptation Plan To Reduce Flooding And Boost Local Economy'. *Inhabitat.com*. 2013. Web. 2015. http://inhabitat.com/copenhagen-unveils-comprehensive-climate-adaptation-plan-to-reduce-flooding-and-boost-local-economy/

[49]Retrieved from Buczynski, Beth. 'INDEX Award Winner: Copenhagen Unveils Comprehensive Climate Adaptation Plan To Reduce Flooding And Boost Local Economy'. *Inhabitat.com*. 2013. Web. 2015. http://inhabitat.com/copenhagen-unveils-comprehensive-climate-adaptation-plan-to-reduce-flooding-and-boost-local-economy/

- Improve preventive infrastructure to cope with damage, loss and traffic disruption

With these targets in place, the city has set a framework to create a safer and healthier environment for the population, to mark the city as ready for internal and external business now into the 21st century. For communities of Kroo Bay and Moa Wharf in Sierra Leone, a comprehensive climate adaptation plan in addition to the current ones is a necessity. Unlike the city of Copenhagen, the economy in Sierra Leone is not in shape to develop a similar plan. Instead, in collaboration with international entities and the Environmental Protection Agency in Sierra Leone, working to mitigate climate change such as the UNFCCC and the IPCC, the target group and the affected stakeholders should develop a plan that will:

1) Help improve the cities resiliency to climate change by improving the infrastructure designs. The infrastructure in Sierra Leone has taken a toll on its infrastructure, roads and housing.

Figure 8: Heavy rain results in Crab Town in Sierra Leone in 2006.
Source: http://news.sl/drwebsite/exec/view.cgi?archive=3&num=3561&printer=1

As Figure 8 shows, the nation (Sierra Leone) is a rather poor country with very limited resources for resilient infrastructure (poorly built houses and roads), which make the cities and communities prone to extreme damages.

2) The population is living near flooded lands, and is more prone to the epidemic. Strategies for adaptation should help reduce these vulnerabilities through actions such as improving sanitation, improving health supplies and deliveries, improved the safe delivery of clean drinking and bathing water. Plans should have components that emphasize on strategies intended to increase funding for health and immunization services.
3) In the same context, bringing support for victims during the recovery process may be an important path to follow to help mitigate some of the physical health effects

and problems resulting from flooding. These measures could mostly include training paid teams and volunteers to help clean up after an event, creating care facilities for children and older people for parents to allow them to concentrate on the recovery process.

4) Another concept that could be integrated is the notion of housing insurance into the West African communities and educated guidance and assistance on insurance.

In fact, as this measure are on the right track, West African communities are poor and cannot afford to participate in these programs. To sum up, from what Copenhagen can teach West African cities, there is a need for much better information, particularly of a quantitative nature, on the potential health effects of flooding, in order to improve strategies to increase adaptive capacity.

- ***Adapting to sea-level rise***

Evidence show that the change in climate and the sea level rise are interconnected and the frequency of these events are increasing. An example of adaptation strategies that could be used as a learning curve is the adaptive management plan used in San Francisco. The San Francisco bay sea level was predicted to rise by about 16 inches by the year 2050 according to the American Planning Association: Climate Adaptation and Sea-Level Rise in the San Francisco Bay Area. And although it is very uncertain, the San Francisco Bay thought that it was important to monitor the changing conditions in order to figure out how to adopt the right strategy. The San Francisco Bay adopted the process of "adaptive management" to which they refer to as necessary because of how uncertain and how fast the changes in the climate could have an impact on people's lives. This

strategy is an interactive process in which managers, scientists, local governments and planners work together to set management strategies, predict possible outcomes, monitor, implement and adjust actions consequently.

The process of adaptation to prevent the damages of sea level rise in countries like Sierra Leone, should include plans that will:

- Make a vulnerability assessment that will include drawing up future sea level rise and areas along the communities at risk of urban heat-island and identify a set of actions that will help decrease that specific community's vulnerability.
- Provide an assessment of the wastewater system by creating scenarios of the current system's performance with future sea level rise projections. This will help decide a set of actions to protect or move the infrastructures where the events are likely to occur.
- Implement the actions according to the adaptive capability of the communities by involving the concerned stakeholders. Involving these stakeholders will include improving their education to climate change, creating projects that will create jobs, which in turn will help improve the economy.

- ***Adapting to droughts***

Droughts are big problems that West Africa have been facing. In fact, as droughts affect agriculture activities, and thus food production. West African communities are prone to disastrous effects. If nothing gets done in a rather rapid matter, it could lead to extreme famine. The adaptation measures to address droughts should be planned early on, in advance so that an appropriate response can be implemented spontaneously. These strategies would include a few large-scale changes in the infrastructure such as defenses

against sea level rise, improvement of roads' quality so they can resist during extremely hot seasons and flooding events. Some other changes should be made in the same context such as showing new ways for the farmers to depend and use less water, like adopting the idea of planting crops that use less water, and that are more resistant to droughts such as beans, corn, oats or potatoes.

Furthermore, even before the issue of global warming became popular, countries in Africa were already vulnerable to droughts events and heat waves. The adaptation measures put in place should also include actions that would the communities strengthen economic growth, climate resistant to improving the agriculture. Projects in this context, would include measures that have demonstrated net benefits, would attract new partnerships with international agencies, attract investors and could generate millions of dollars in the economy annually.

Finally with the lack of data and increase uncertainty, adaptive measures in cities like Dakar in Senegal, early warning and response should be incorporated along with policies and frameworks within the communities to address the drivers and risk caused by droughts and limit the vulnerabilities.

C- Risk Disaster and Environmental Management

The concept of risk disaster management came from the idea that no-one can escape natural disasters such as floods, droughts, earthquakes. They happen and people get caught up in it. Risk Disaster Management or Disaster Risk Management (DRM) aims reduce or limit the damages caused by these natural disasters. DRM depends on how severe the natural event was and how severe the impacts are on the environment and the population. This concept refers to practices and strategies put in place to reduce risk

and exposure to natural hazards, reducing the population and environmental vulnerability through ethical and efficient efforts to analyze and reduce the key drivers of these disasters.

According to the IPCC Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC, 2012), an effective risk management strategy would generally involves a set of actions that will aim to reduce and transfer risk and to respond to events and disasters, as opposed to a singular focus on any one action or type of action[50].

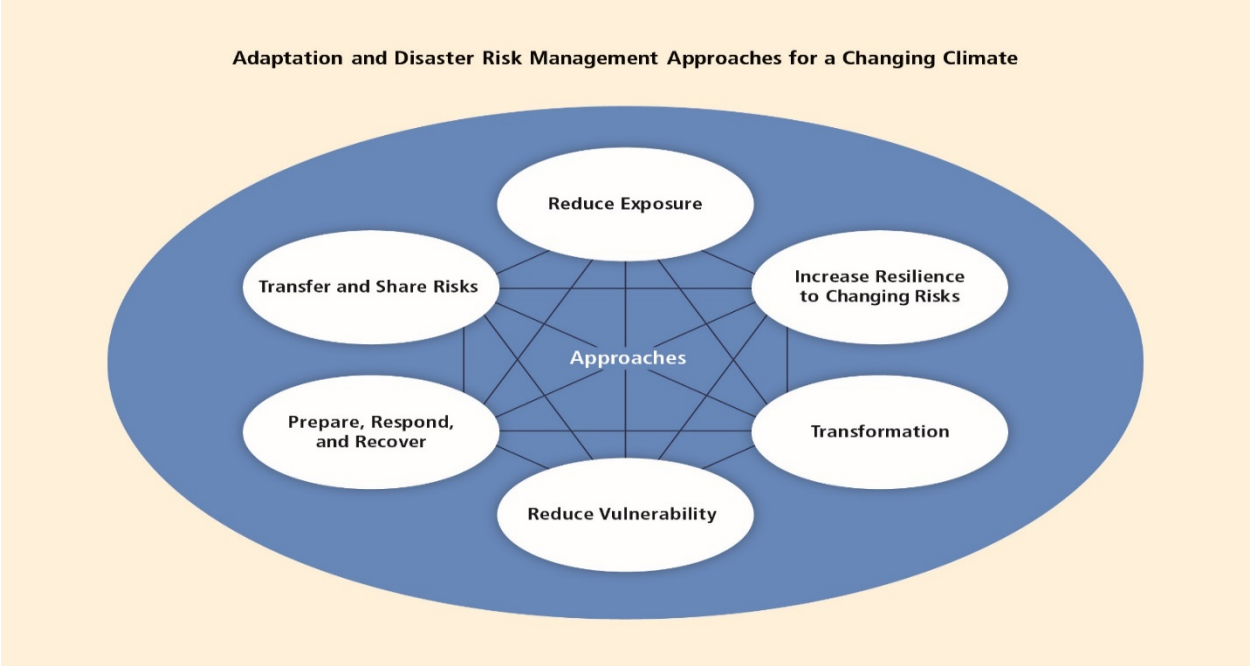

Figure 9: Adaptation and disaster risk management approaches from the IPCC report for reducing and managing disaster risk in a changing climate. Source: https://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf

[50] Retrieved from IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp. https://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf

Typically, DRM approaches for poor communities like cities on Sierra Leone, Senegal should provide actions that will help the communities directly by providing support for the losses, preventing the effects, educating and informing the stakeholders. The idea is that the communities in West Africa do not have the resources to respond to the impact of natural hazards and to the costs of adaptation measures. These measures are meant to increase awareness of climate change and incite the population to changing lifestyle, improving and moving economic activities, infrastructures, and wastewater and sewage management[51].

Furthermore, the implementation of these measures and metrics will create some difficulties. In fact, according to the Center for Climate Strategies Adaptation Guidebook, some of the limitations in carrying out these measures are value, which implies how people from one place would value one gallon of water in comparison to another place, functionality, which concerns the use of water per capita and finally, the spatial and temporal variation, which concerns the instability of water resources. These limitations could be overcome through the participation of the water-stressed stakeholders, focusing on measuring inputs instead of outputs of water and a combination of supply and demand sectors.

[51] Retrieved from Langis, Joanne. *Adaptation Measures for Floods, Storm Surges, And Sea Level Rise*. 1st ed. Moncton: Groupe Littoral et vie Universite de Moncton, 2013. Web. 2015. http://www8.umoncton.ca/littoral-vie/Adaptation%20measures%20(Littoral%20et%20vie).pdf

CONCLUSION

Yes, climate change is real and is happening. There are no longer theories of the accelerated warming of the planet but evidence and proof and it has become a great concern worldwide. Not only it affects our future generations, but it has great significance for sustainable development plans, human lives, their livelihoods and the ecosystem. The diversity of climates globally is making it very hard to make accurate assessments of the present and future damages either economically or politically.

Nevertheless, the impacts of climate change on the natural resources of a region depend on the changes in the atmosphere, its effects on temperatures, and impacts on the ground level. Water plays a critical role in the development of economic growth and reduction of poverty in West African countries. Evidence shows a rapid increase in demand for water in industries, including mining, hydropower generation, agricultural activities and domestic consumption. But satisfying these demands is more challenging in the two focus cases, Sierra Leone and Senegal, where clean water is scarce and expensive. The available water supply is depleting and the environmental degradation is increasing.

West Africa has experienced huge water and rain patterns modifications over the past years. On one hand evidences show that sea-level rise is threatening many coastal cities like Kroo Bay and Moa Wharf in Sierra Leone with flooding, while changes in rainfall and temperature will shift disease patterns, wildlife habitat, and river flows. These flooding events make the populations and communities much more vulnerable to diseases and displacement. On the other hand, water-stressed cities like Dakar in Senegal, extreme droughts events are threatening the water supply, not satisfying the increasing demand.

Furthermore, these events frequency and strength have been projected to increase in the next 50 years.

In order for these communities to survive, a few adaptation plans have been put in place to help reduce their vulnerabilities and increase their resilience. But some extra efforts are in need. Adapting to floods, sea-level rise and droughts will require learning from other successful adaptation strategies, and most of all, the participation of the communities. Another plan would be Disaster Risk Management (DRM) which will aim to help reduce to projected future impacts by measuring and preparing scenarios. The modeling of these scenarios will contribute to creating and implement projects in the water sector that will focus on the current problems and help the communities recover from past climate events.

Human lives are sacred, and it is our responsibility and our turn to help each individual living in these poor communities. The adaptation plans and metrics to increase the resilience of Sierra Leone and Senegal should help attract investors, and international organizations that would put more efforts, time and resources on limiting the damages of climate change, a phenomenon that is affecting now and will affect future generations.

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Curriculum Vitae

Tanobla Aurelie Konin was born and raised in Cote D'Ivoire, West Africa. Prior to enrolling in the Johns Hopkins University Advanced Academic Programs in spring of 2014, Aurelie spent 5 years developing her studies while receiving her Bachelor of Science in the field Major of Chemistry and Business in Wichita Kansas. Aurelie has been in numerous roles as an intern and associate scientist in the pharmaceutical industry. These experiences have allowed her to gain valuable experience in research and business. She also had the opportunity to work with expert professionals in the Research and Development department (R&D) at Hospira Inc. where she learned how to conduct technical research on stability chemistry samples. Additionally, she has a strong background in accounting, finance and management. When it comes to her work, she is focused, helpful to others and can multi-task.

However, with a multidisciplinary background, Aurelie became very interested in energy-related policy issues such as environmental issues, global climate change, sustainable development, and energy sustainability which are no doubt key strategic issues that need to be addressed. While working as an intern at the United Nations Foundation, she learned more about energy policy, consumption and the science behind energy use in residential and corporate infrastructures and how it affects our environment, in regards to the emission of greenhouse gases. Aurelie is a native French speaker. She received a Master of Science degree in Energy Policy and Climate at Johns Hopkins University in Washington, DC.